ACESYS III Forum

Transplant Production in Closed Systems with Artificial Lighting for Solving Global Issues on Environmental Conservation, Food, Resource and Energy

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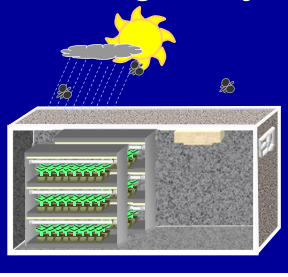
Contents

Transplants:

Small plants to be transplanted in the field or in the greenhouse, which are produced from seeds or macro-/micro cuttings under non-sterile or sterile conditions.

Closed Systems:

1) Covered with optically-opaque thermal insulators,
2) Ventilation is restricted at minimum,
3) Use of artificial light only.



Thousands of billions of **quality and productive transplants** are needed to solve concurrent global issues on:

1) Food,
2) Energy/Resource and
3) Environment

in the 21st Century.

Quality and productivity of transplants are significantly affected by physical, chemical and biological environmental factors.

These factors can be controlled best in closed systems with artificial lighting.

Quality transplants:

1) free from pathogens,
2) superior genetic/physiological characteristics,
3) vigorous growth, high yield and quality with minimum use of resources after transplanting.

Advantages of closed systems

- Easy environment control,
- Multi-shelves can be used,
- Dehumidified water can be recycled, and CO_2 is mostly used,
- Global technical standards,
- No pesticide and no emission of agro-chemicals,
- Comfortable working environment

It has been considered that transplant production under artificial light is costly, because:

- High operation (or electricity) costs for lighting and air conditioning,
- High initial investment cost for structures and equipment.

Hypothesis

Overall energy and material inputs are lower when using transplants grown in closed systems than when using transplants grown in open systems.

Overall energy and material inputs are the sum of those in:

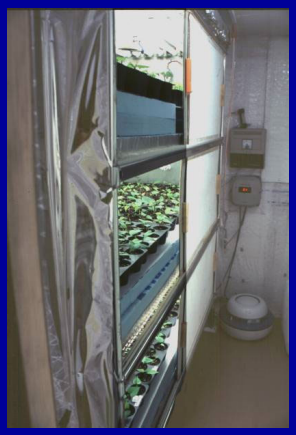
- Transplant production,
- Crop production, and
- Environmental conservation.

Objectives are to show:

1) Operation costs for lighting and air conditioning are low.
2) Initial costs of fluorescent lamps in multi-shelves and home-use air conditioners are low.
3) Quality and productivity of transplants produced under artificial light are high.

Amounts of electricity required for lighting during transplant production are small, because

1) PPF is 200-400 μmol $m^{-2}s^{-1}$,
2) Production period is 10-30 days,
3) Planting density is 400-1000 plants m^{-2},
4) Transplants are 20-30 cm apart from fluorescent lamps.

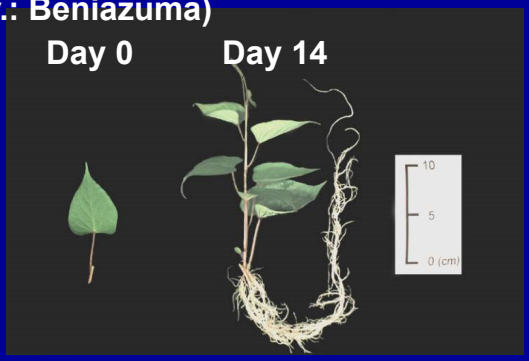


Lab. Scale Model of the Closed System

3 shelves, 5 trays/shelf

Plant material

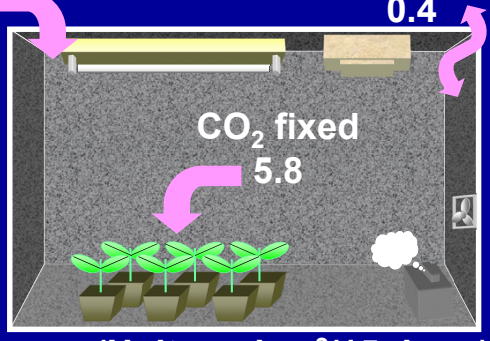
Sweet Potato (*Ipomoea batatas* L. (Lam) cv.: Beniazuma)



CO_2 balance of the System

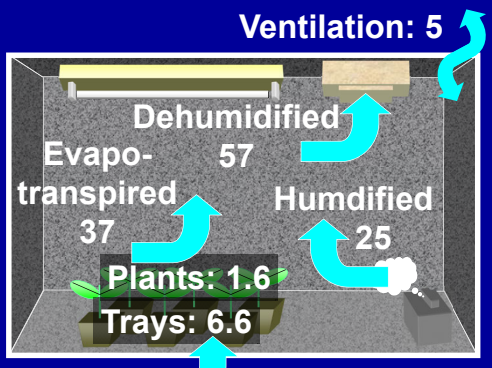
CO_2 supplied: 6.2

CO_2 released 0.4



(Unit: mol m^{-2}/15 days)

Water balance of the System



Irrigated: 50 (Unit: kg m^{-2} /15 days)

Water Utilization Efficiency: E_w

$$E_W = \frac{(D + C_P + C_S) - V}{I + H}$$

Amounts of water (kg m^{-2} $time^{-1}$)

- I: Irrigated
- H: Humidified
- D: Dehumidified
- C_P: Stored in plants
- C_S: Stored in soils
- V: Released by ventilation

Water Utilization Efficiency:

When dehumidified water is recycled:	0.80
When dehumidified water is not recycled:	0.04

Water Utilization efficiency is 20 times greater when dehumidified water is recycled than when it is not.

Percentages of Electric Energy Consumption of the Components of the Closed System

Lamps :	76 %
Air Conditioner:	16 %
Fans etc. :	8 %

Electricity cost to produce a single node cutting of sweetpotato:

370 kJ = 0.11 kWh (or 1 US Cents)

A virus-free transplant of sweet-potato is about 1 US $ in Japan

Production of value-added transplants

1) Pathogen and pest free sweetpotato,
2) Tomato and eggplant with controlled flower bud development,
3) Spinach with controlled bolting,

Transplant production in closed systems can be competitive, in terms of energy and material inputs as well as economical profit, to that in open systems, and can be commercialized.

A closed transplant production system with artificial lighting on a pilot scale is currently under construction in Chiba University.

The closed transplant production system is physically divided into:

1) Transplant production area,
2) Working area,
3) Storage area,
4) Equipment area, and
5) passing area

1) No workers can enter the transplant production area.
2) Trays are transported automatically between transplant production area and working area.
3) Nutrient solution supply in the transplant production area is also conducted automatically.

The transplant production system are deigned to:

1) maximize the holding capacity of the basic modules
2) minimize the number of changes when a thousand basic modules are integrated in the future.

The computer software system consists of:

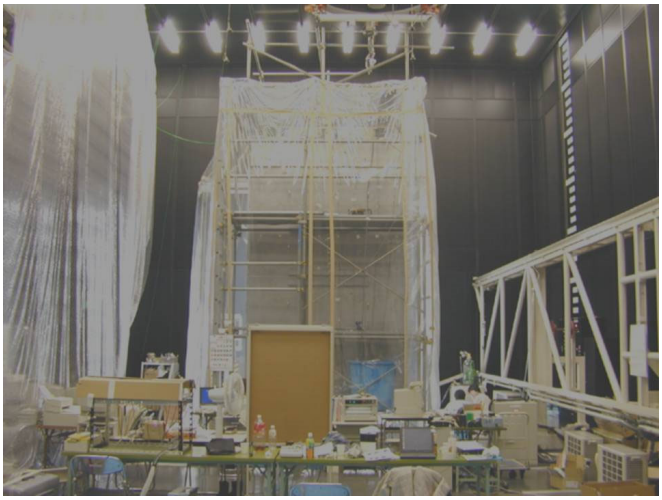
1) Environment measurement and control subsystem,
2) Tray transportation subsystem,
3) Plant growth measurement subsystem,
4) Production support subsystem,
5) Alarm subsystem.

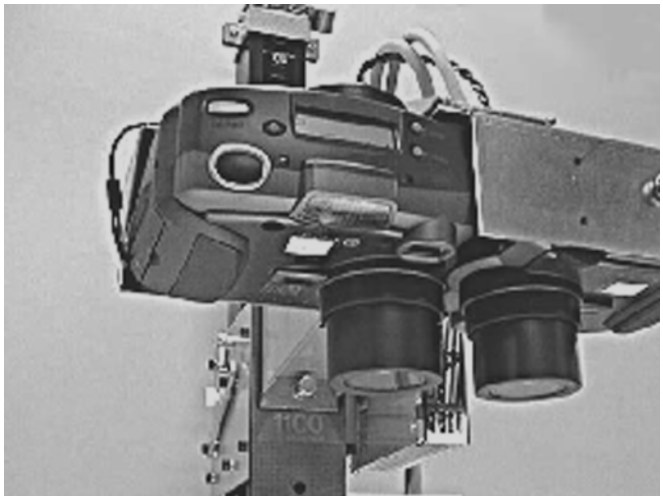
The basic module with 7 shelves is:

1) 400 cm high, 267 cm long, and 69 cm wide,
2) holds 56 plug trays,
3) with 112 fluorescent lamps (36 W) ,
4) with a distributed, intelligent microcomputer

The basic modules are designed to:

1) maximize the holding capacity and handling speed of trays
2) minimize the handling distance of the trays.





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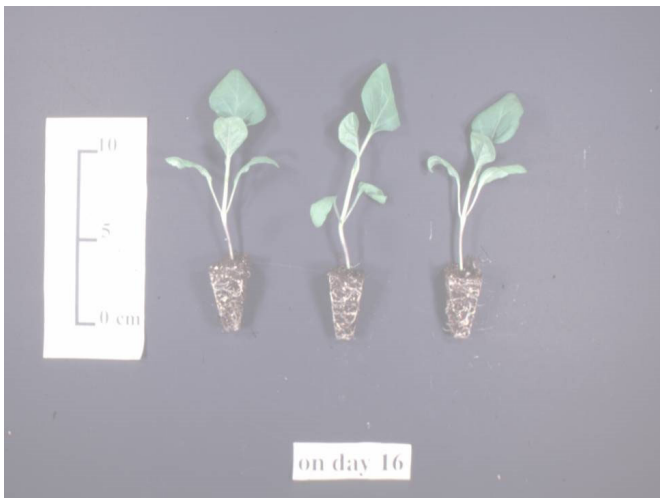
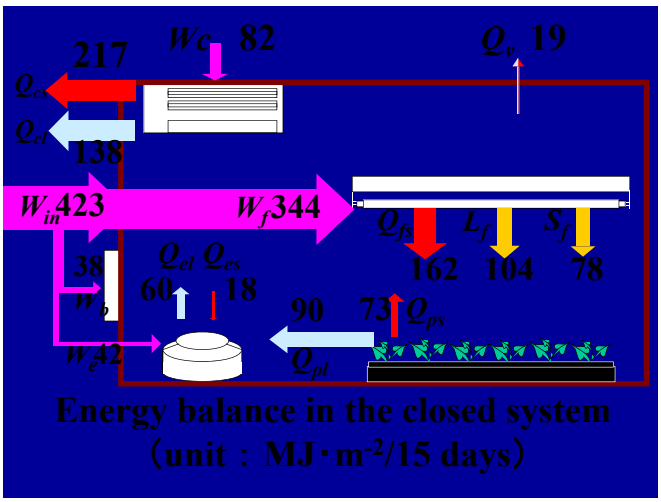
Conclusion

- Transplant production in closed systems is not energy and material efficient and does not pollute environments significantly.
- Quality/productivity of transplants are high when produced in closed systems.
- Its commercialization is possible in the near future.





Energy balance in the closed system
(unit : MJ·m^{-2}/15 days)

$$\frac{\text{Chemical Energy Fixed as Dry Matter}}{\text{Electric Energy Consumed by the System}} = 0.007$$

$$\frac{\text{Chemical Energy Fixed as Dry Matter}}{\text{Shortwave Radiation Energy Received}} = 0.04$$